THE BASIC MASSIVE ROCKS OF THE LAKE SUPERIOR REGION.

III. THE GREAT GABBRO MASS OF NORTH-EASTERN MINNESOTA.[1]

A. Introduction.

As HAS already been stated in an earlier paper,[2] the writer purposes, as time and opportunity permit, to discuss the petrographical and stratigraphical relationships of the basic rocks that constitute such an important element in the geology of the country bordering Lake Superior. In the series of papers, of which this is the first, the petrographical characteristics of the various types of these rocks will be described, and the views held by previous workers with respect to their geological relationships will be outlined. Thus, it is hoped, a foundation will be laid for a new and more thorough investigation of the field relations of these rocks than has heretofore been possible. As the case now stands, several of the geologists who have investigated the eruptive rocks of this region have erred in confusing types of entirely different origins, and have thereby introduced into the literature errors of observation that have rendered a clear understanding of the Lake Superior geology almost impossible.

When practicable the laboratory and field study of rocks should proceed together, each aiding the other in solving the knotty problems that so often arise in their progress. The laboratory study of the eruptives in the region under consideration has been almost entirely neglected, and consequently the field problems arising in connection with them have largely remained unsolved. When the peculiarities of these rocks—their composition and structure—become known, much light will be thrown upon their nature, and it will then be time to again review their field relations, when it is believed that many

[1] This Journal, Vol. I., pp. 433 and 587.

[2] This Journal, Vol. I., p. 435.

of the difficulties now surrounding them will disappear. At present the main results reached by the field-geologists who have busied themselves with the rocks under discussion will be referred to. They must pass unchallenged except in the few cases where the microscopic evidence is directly at variance with them; and when there is no field evidence directly substantiating them. At some time in the near future it is hoped that an opportunity will offer itself for a more detailed study of the rocks in the field. Then it will be proper to criticise the conclusions arrived at by previous workers, and to suggest new views as to the position and relation of the eruptives with respect to the rocks with which they are associated.

B. The Position of the Gabbro.

The great gabbro mass which is the subject of this paper has been placed by Irving in the Keweenawan group, the separation of which from the underlying Huronian slates and quartzites and the overlying Cambrian sandstone, is due principally to the investigations of Brooks, Pumpelly, Irving and Chamberlin. The history of the discussion which has led to the recognition of the great Keweenawan series it will not be necessary to outline, as it is well given in the essays, whose authors have been named.[1]

The only detailed description of the series as a whole has been given us by Irving,[2] who makes it "include only the suc-

[1] It should be stated here that although the individuality of the copper-bearing series of rocks is recognized by nearly all geologists who have worked in the Lake Superior region, several have declined to regard it as a distinct series, equivalent to the Huronian or the Cambrian. These geologists prefer to look upon it as belonging with the latter group as its lower member. Dr. Wadsworth has long held this view, and Prof. N. H. Winchell (8th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., p. 22; 17th ibid., pp. 54-55) in one of his most recent reports sums up the work of the Minnesota Survey in this direction in the statement that the Keweenawan series is closely linked with "the great gabbro flow," to which reference will be made hereafter, and that both are members of the Potsdam. In a later report (20th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., p. 3) the same writer discusses the age of the gabbro and concludes that it is much older than the Potsdam, but he does not assert positively that the Keeweenawan beds overlying it are pre-Cambrian.

[2] The Copper-Bearing Rocks of Lake Superior, R. D. Irving: Monograph V., U. S. Geol. Survey, Washington, 1883.

cession of interbedded 'traps,' amygdaloids, felsitic porphyries, porphyry-conglomerates, and sandstones, and the conformably overlying thick sandstones, as typically developed in the region of Keweenaw Point and Portage Lake on the south shore of Lake Superior."[1]

Although no distinct line of division between them can be pointed out, the beds of the series naturally fall into an upper division made up wholly of detrital material, principally shales and red sandstones, and a lower division consisting chiefly of a succession of basic flows, layers of conglomerate and sandstone and quite a large proportion of flows of acid eruptive rocks. The thickness of the upper division is estimated at 15,000 feet at its greatest, and that of the lower division at from 22,000 to 24,000 feet.

The recent discovery that the central part of the Keweenawan is underlain unconformably by a great mass of anorthosite, which along the middle portion of the Minnesota coast comes to the surface in many places, suggests to Lawson[2] that the maximum thickness of the lower Keweenawan beds at this place must be much less than Irving's estimate. His own figures are only about one-tenth those of Irving. VanHise[3] in a review of Lawson's article takes exception to the author's small estimate, and prefers to accept Irving's figures, until these are proven inaccurate by careful detailed investigation of the problem in the field.

Since it is only in the lower division that eruptive rocks occur, our attention will be confined entirely to this. It is not possible to determine positively for the entire series the actual succession of the subordinate members belonging in it, for this, in an eruptive series, may vary in different areas, but Irving believes that the following "broad horizons" may be recognized: (1) a succession of heavily bedded coarse-grained olivine and orthoclase gabbros, forming the base of the series; (2) a series of olivine diabases and diabase-porphyrites, occurring at the lower hori-

[1] l. c., p. 24.

[2] Geol. and Nat. Hist. Survey of Minn., Bull. No. 8, p. 21.

[3] Jour. of Geology, Vol. I., p. 312.

zons, together with acid eruptives of all kinds common to the group, as quartz-porphyries, quartzless-porphyries, and fine-grained red granites; (3) olivine-free diabases and other basic rocks with amygdaloidal upper and lower surfaces; and (4) detrital beds, chiefly porphyry conglomerates and sandstones, rare in the lower third of the series, but increasing in thickness and frequency towards the top. These various subordinate divisions have been separated into smaller sub-divisions, and their sequence, where possible, has been carefully detailed, but since a discussion of this classification is not necessary to our present purpose it need not be entered upon.

The lowest of the divisions of rocks belonging in Irving's Keweenawan has been said to consist of a succession of heavily bedded coarse-grained olivine and orthoclase gabbros. The best exhibition of these gabbros is found in north-eastern Minnesota, where the area underlain by them occupies about 2100 miles of the surface of the state, extending from the east line of Range 1, E., to about the middle of Range 15, W. The general shape of the area is crescentic with the concave side turned toward Lake Superior and its convex side facing the north-west. In its widest part the crescent measures about twenty-two miles from south-east to north-west. The chord connecting its two horns is about 125 miles in length. The eastern extremity forms a narrow point about three miles north-west of Greenwood Lake, from which point the area extends westward, widening gradually until it reaches its broadest expanse, and then gradually contracting until it finally abuts against the north shore of St. Louis Bay west of Duluth, where it appears as a band forming the shore line for ten or twelve miles, beginning in the western portion of the city of Duluth and ending four miles east of Fond du Lac.

A second[1] area of basal gabbro is in the Bad River region in Wisconsin. Here the rock forms a narrow belt about forty-eight miles in length and from two to five miles in width, stretching from the Gogogashugun river south-westward to near Numakagon lake, in T. 43 N., R. 6 W., Wis.

[1] Cf. pl. XXII., Copper-Bearing Rocks.

It was not until a few years since that an attempt was made to discover the true relations of these gabbros to the surrounding rocks. In his Copper-Bearing Rocks (p. 266) Prof. Irving places them at the base of the Keweenawan group, at the same time stating that "There is no definite evidence of unconformity between the gabbros and the slates of the Saint Louis River," regarded as Animikie. In a later paper the same writer[1] refers to a coarse-grained, stratiform olivine-gabbro at the base of the Keweenawan.

Though nowhere so stated, the olivine-gabbros had by this time been separated by the author from the overlying "orthoclase gabbros," and had been placed by him at the very base of the Keweenawan group, with the orthoclase-gabbros immediately above them. In his article[2] on the classification of the early Cambrian and pre-Cambrian formations, we have this description of the position and nature of this great mass of rocks, ". . . . We find at the base of the series [Keweenawan] an immense development of stratiform, fresh and often exceedingly coarse olivine-gabbro, the individual layers of which, notwithstanding their complete crystallization, very coarse grain, and lack of amygdaloidal or dense upper surfaces, seem evidently to have formed great flows at the surface of the region as it stood at the time of their extrusion."

No more explicit statements of his views concerning this basal gabbro appear in any of Irving's writings. A reference to the geological map of north-eastern Minnesota accompanying the paper last referred to, will, however, show that at this time (1886) he believed the basal gabbro in Minnesota to rest unconformably upon the Animikie, since the former is represented as cutting transversely belts of St. Louis slates, the Mesabi granite and schists of the Archean, and the eastern area of Animikie slates along the boundary line between Minnesota and Canada, which slates here strike nearly east and west.

Although in his maps the "gabbro flow" is represented as

[1] Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 204, 249.

[2] Seventh Ann. Rept. U. S. Geol. Survey, 1888, p. 419.

belonging with the Keweenawan rocks, the Wisconsin mass was nevertheless recognized by Irving as presenting "the appearance of a certain sort of unconformity with the overlying beds. These gabbros, which lie immediately upon the Huronian slates, form a belt which tapers out rapidly at both ends, and seems to lie right in the course of the diabase belts to the east and west, since these belts, both westward toward Lake Numakagon, and eastward toward the Montreal river, lie directly against the older rocks, without any of the coarse gabbro intervening." . . . "The great extent of coarse gabbro in Minnesota seems to sustain somewhat the same relations to more regularly bedded portions of the series." [1]

The only other descriptions of this great gabbro mass are to be found in the reports of the Minnesota survey. In the report for 1887 Prof. N. H. Winchell[2] details a few of his observations on the "great gabbro flood," and surmises that the "flow" did not escape through a single fissure. The structure of the rock is reported as roughly columnar, with sometimes apparent indications "of the existence of imbricating layers having a gentle dip, as if the fluid rock had swept over the country in successive tides. . . . In texture the gabbro is characteristically coarse. Sometimes some of the constituent minerals are half an inch in diameter. From this they graduate down to an extreme degree of fineness."

From the macroscopic descriptions of other varieties of the rock that follow it is evident that the writer is not dealing exclusively with specimens taken from the great "gabbro flood" at the base of the Keweenawan, for, as the sequel will show, this is composed of a rock which, in its unaltered state, possesses a remarkably uniform texture, and is so well characterized that any departure from it is presumptive evidence that the rock exhibiting the variation belongs not in the "basal flow," but in some one of the numerous smaller beds interstratified with the Animi-

[1] Copper-Bearing Rocks, p. 155.

[2] Geol. and Nat. Hist. Survey of Minnesota, 16th Ann. Rept. for 1887. St. Paul, 1888, pp. 360-362.

kie and the Keweenawan strata at various horizons, or in some one of the many dykes cutting these.

In the report[1] of the following year, upon referring to the position of the gabbro with respect to the other formations, Prof. Winchell says . . . "In general the gabbro lies on the Animikie (Taconic) in Minnesota." At Chub (Akeley) lake, however, it seems to be underlain by a bed of quartzite, regarded as a lower member of the copper-bearing formation of the Potsdam (Keweenawan of Irving and Chamberlin) in the seventeenth report, but looked upon as Animikie and denominated the Pewabic quartzite in the sixteenth report,[2] and described under the field name "muscovado" in earlier reports.

In a more recent discussion[3] as to the age of the gabbro, Prof. Winchell briefly summarizes his previous views on the subject, and concludes that the supposed quartzite underlying the gabbro belongs near the bottom of the Animikie, and since the eruptive rock is so closely associated with the fragmental one, that the former must be of nearly the same age as the latter.[4]

This conclusion is based on the supposition that the rocks immediately underlying the gabbro are fragmental quartzites that have been altered by the eruptive for miles even from its contact with them.[5] But this is probably not always the case. As the writer[6] has shown in another place, some of the so-called quartzites are very basic crystalline aggregates of pyroxene and olivine, and others are granulitic phases of the overlying gabbro. Since they are portions of the gabbro they are of the same age as this, and are not available as stratigraphical data for use in determining the time relations of the great "flow" with respect

[1] 17th Ann. Rept. for 1888. St. Paul, 1891, p. 52.

[2] 16th Ann. Rept., pp. 82-87.

[3] The Iron Ores of Minnesota. Bull. Minn. Geol. Survey, No. 6, 1891, p. 125.

[4] Cf. also: 20th Ann. Report, p. 2.

[5] H. V. WINCHELL: Ib. p. 127.

[6] BAYLEY W. S.: Notes on the Petrography and Geology of the Akeley Lake Region in Northeastern Minnesota. 19th Ann. Rept. Minn. Survey. Minneapolis, 1892, p. 193 et seq.

to the Animikie and the Keweenawan rocks. Some of the rocks, called by Winchell Pewabic quartzite, are probably true Animikie fragmentals, or metamorphosed phases of these, but even in this case there is no proof that the gabbro immediately succeeds them in point of age. The evidence would simply indicate that the eruptive is younger than the Animikie. It would not fix its age more definitely. The observations of Winchell would thus seem to lead to the same conclusion as that reached by Irving in so far as the latter supposed the gabbro to be post-Huronian.

Upon returning again to the problem as to the age of the gabbro Winchell [1] attempts to fix this more definitely by assuming the identity of this rock with the anorthosite, which is shown by Lawson to be older than the bedded Keweenawan. But it is impossible at present to assert with any degree of certainty, that the two rocks are the same (although VanHise holds with Winchell that their equivalency is possible), for the one has not been traced into the other, nor has the upper limit of the gabbro been carefully studied. This great mass may be much older than the lowermost beds of the Keweenawan series, but as yet there has been cited no proof in favor of the view.

So far as the little evidence at hand enables us to judge, the gabbro whose petrographical characteristics are discussed in this article, forms a great mass of enormous extent above the Animikie but below the interbedded flows and fragmentals of the Keweenawan series in Minnesota. There are obscure indications that the mass is a great layer composed of successive flows that followed one another so rapidly as to give no opportunity for the action of erosion processes or for deposition between them. If this be so the lack of more apparent bedding is doubtless due to the great thickness of the individual beds, as is also their coarse grain. There are some things about the mass, however, that suggest another origin for it. "The great coarseness of grain, the perfection of the crystallization, the abrupt termination of the belts, the complete want of structure, and the presence of intersecting areas of crystalline granitoid rocks — all suggest the

[1] Bull. No. 8. Geol. and Nat. Hist. Survey of Minn. p. xviii.

possibility that we have here to do with masses which have solidified at great depths. They certainly cannot, however, be regarded as intrusive in the ordinary sense of the word; so that, unless we regard them as great outflows, we should be forced to look upon them as the now solidified reservoirs from which the ordinary Keweenawan flows have come."[1]

C. Petrographical Description of the Normal Phase of the Gabbro.

Up to the present time there has appeared no general petrographic description of the great gabbro supposed to be at the base of the Keweenawan, although both Irving and Wadsworth have given detailed descriptions of hand specimens taken from it. The former writer,[2] in his monograph on the copper-bearing rocks, refers to the great mass at Duluth as consisting principally of a coarse orthoclase gabbro, but including some orthoclase-free gabbro. The rock is "massive and irregularly jointed, making great ledges facing in different directions, and furnishing bare rounded summits to the hills which it composes.

The prevalent type of the gabbro . . . is of a light gray color, and very coarse-grained, single feldspar crystals sometimes reaching even an inch or two in length. The augitic ingredient is plainly in greatly subordinate quantity, and often on a fresh surface its presence cannot be detected at all. On exposed surfaces, however, the weathering generally brings it out, and then it can be plainly seen to fill the spaces between the feldspars. Titaniferous magnetite is also often perceptible to the naked eye in large particles.

Less commonly the grain is finer and the color darker, the augitic ingredient at the same time becoming more plentiful. In the thin section the predominant feldspar is seen to be a plagioclase belonging near the oligoclase end of the series. There appears also to be a younger feldspar present, which has the character of orthoclase and fills corners between the plagioclase crystals, around whose contours it moulds itself sharply. Streng and

[1] Copper-Bearing Rocks, p. 144.

[2] Copper-Bearing Rocks, Mon. V., U. S. Geol. Survey, p. 266 and 269.

Kloos[1] found 1.61 per cent of potash in the rock, which they very properly regarded as belonging to orthoclase. The spaces between the feldspars are filled with a diallage which is always more or less altered to greenish uralite. The alteration in many sections is carried beyond uralite to chlorite. The magnetite is very large, abundant and titaniferous. Apatites of large size are found in all sections. Biotite is not an uncommon accessory. Olivine is absent from all sections."

It is very evident that the writer is not describing by these words the rock of the great 'flow' as he defined it in his later papers, but that he is dealing exclusively with the orthoclase gabbros, which were afterwards separated from the underlying mass and given a position just above this.[2]

The only specimen of the true basal gabbro examined by Irving[3] came from the Cloquet river, in Sec. 34, T. 53 N., R. 14 W. in Minnesota. This he characterizes as "A very fresh olivine-gabbro. It is light gray in color, very coarse grained, and [is] composed chiefly of very fresh plagioclase (anorthite). Quite fresh diallage fills in the space between the feldspars. A few large fresh olivines occur here and there in the section. Titaniferous magnetite is abundant, and large sized, and biotite occurs in a few small scales."

Dr. Wadsworth[4] made no attempt to describe the general features of this great mass of rock. His descriptions are of hand specimens furnished him for examination by the officers of the Minnesota survey. Among them were several representatives of the "basal flow,"[5] but these were not studied with reference to each other, except in regard to their alterations.

[1] Neues Jahrb. f. Min., etc., 1877, p. 113.

[2] See ante, p. 692.

[3] Copper-Bearing Rocks, p. 272, also p. 46.

[4] Geol. and Nat. Hist. Survey of Minnesota. Bull. No. 2.

[5] The specimens described by Dr. Wadsworth that are thought to belong to the basal gabbro are the following: No. 696, p. 69; 706 and 702, p. 70; 773 and 713, p. 71; 699, 769 and 701, p. 72; 689 and 721, p. 75; 780, p. 85; 707, p. 87; 693, p. 88; 694, 704 and 703, p. 89; 787, p. 90; 715, 692 and 777, p. 91; 691, p. 92; 700, 714 and 698, p. 93; 705, p. 94; 514 and 513, p. 95; 697 and 776, p. 96; and 781, p. 97.

It has already been intimated that the normal rock of the great gabbro is so uniform in its general character that, after studying carefully one of its hand specimens, others might easily be identified among a collection of specimens of the basic rocks of the Lake Superior region, without much danger of error. Its description, therefore, is quite a simple matter. In its macroscopic aspect the normal rock is a medium to coarse-grained, gray, granular aggregate of a very lustrous plagioclase and a black augite. The plagioclase is usually more abundant than the darker mineral; its dimensions are larger, and its contours more frequently approximate to those of crystals. It is of a light gray color and has a glassy lustre on fresh fractures, while on weathered surfaces it is white and opaque. Twinning striations are visible on nearly every grain. The augite on the contrary is jet black. Its cleavage faces are rather small, and its contours never approach those of crystals; they are occasionally triangular or wedge-shaped when they have any definite form, but are usually very irregular in outline. In some of the coarse-grained varieties of the rock there is a rudely lamellar arrangement of both the augite and the feldspar, so that the mass possesses a platy structure. With this exception the gabbro has the typical granitic texture, and is thus easily distinguished from all the other so-called flow gabbros of northeastern Minnesota and the region bordering on Lake Superior in which is more or less perfectly developed the diabasic texture.

The principal varietal differences noted in the rock are due solely to the proportions of feldspar, augite and olivine present in it. When the pyroxene is in moderate quantity the appearance of the specimen is as indicated above. Sometimes the feldspar is largely in excess, and pyroxene has almost entirely disappeared. Now the rock has a lighter gray color, and the bright shining black particles are lacking. Again olivine is the principal component when the tint of the rock becomes dark green. The structure in all cases, however, remains the same. The varieties are merely local phases of the predominant rock for on all sides they grade into one another by insensible transitions. The

density of the varieties depends of course upon their composition; the larger the proportion of feldspar present the lower the specific gravity. Of the three specimens whose densities were determined, one (10440) was found to have a specific gravity of 2.8061, another (8786) of 2.9475, and the third (8589) of 3.0636.

The sections of nearly all specimens taken from the interior of the gabbro area, or from points at some little distance from its northern edge are similar, in that they represent a very fresh rock, whose structure is monotonous and whose composition is quite simple. All contain magnetite, olivine, pyroxene and plagioclase as primary constituents, and many have in addition as secondary components, biotite, chlorite and quartz. The proportions of secondary products present are never sufficiently large to affect the characteristics of the rock as a whole, though they be abundant enough to change materially its appearance in thin section. The usual succession in the formation of the primary minerals is as indicated, and in this respect does the gabbro of the mass under discussion differ most essentially from the other "gabbros" of the same and neighboring regions, for in all of the latter rocks studied the pyroxene is younger than the plagioclase.

The feldspar is the most abundant of the essential components, sometimes constituting, as it does, almost the entire section. It is nearly always in large grains, whose contours are very irregular in shape, and only very rarely resemble those of the lath-shaped grains of diabasic plagioclase. The mineral is quite fresh and is devoid of secondary inclusions, other than a few flakes of kaolin and small flecks of some chloritic substance. The characteristic acicular inclusions of gabbroitic feldspar are sometimes absent from the plagioclase of the Minnesota rock, but more frequently they are present in the usual forms. Small areas of augite and little grains of biotite and magnetite are also enclosed in the feldspar, and dust-like particles are scattered everywhere throughout the grain. The inclusion of augite within the plagioclase would seem to show that the latter mineral is undoubtedly younger than the former; but certain triangular areas of pyroxene between grains of plagioclase would point to

the opposite conclusion. The amount of plagioclase in all portions of the gabbro mass is so great that it must have occupied a long period in its separation. It is probable that the augite began to separate from the magma that yielded the rock some time before the plagioclase, but that after the feldspar began to crystallize the two minerals grew side by side until all the pyroxenic material of the magma had been extracted from it, when the feldspar continued its growth unaccompanied by the formation of pyroxene. Thus some of the plagioclase is older than some of the augite, though the greater part is younger than the great mass of this mineral.

All the plagioclase grains are traversed by broad twinning lamellæ, the maximum extinction on each side of whose composition plane is about 35°. In order to determine accurately the nature of this plagioclase, the three specimens whose densities are given, were powdered and their feldspars separated by the Thoulet solution. Most of the mineral was precipitated when the density of the solution was between 2.674 and 2.728, the limits in the different cases being as follows: in specimen 8786 between 2.700 and 2.728; in 8589 between 2.700 and 2.711, and in 10440 between 2.674 and 2.712. As a small amount of the plagioclase in each specimen was more or less altered, the average of the above figures may be taken as representing the average density of the plagioclase in the gabbro. The method is justified in the fact that the optical properties of the powder in all cases was exactly the same, and that its precipitation was not in steps or stages, but was continuous between the limits mentioned. The mean density of the feldspar separated from the three rocks was thus 2.701, which indicates a very basic labradorite. In the feldspar of a specimen of the gabbro from the Cloquet river Irving[1] reports 52.40 per cent. of SiO_2, while for the most acid member of the bytownite series Tschermak[2] calculates 49.1 per cent. of SiO_2. The largest quantities of the powder in the above three cases fell respectively at 2.700, 2.711 and 2.712.

[1] Copper-Bearing Rocks, p. 439.

[2] Lehrb. d. Mineralogie, 2te Aufl. 1885, p. 439.

There can thus be no doubt that the feldspar throughout the entire mass of the rock is practically of the same character, since the three specimens tested were taken from three widely separated portions of the gabbro area, and each represents a distinct type of the rock. No. 8786 is very rich in olivine, No. 8589 contains much augite and a large quantity of brown biotite, while No. 10440 is very rich in feldspar and quite poor in pyroxene.

An analysis of the feldspar separated from No. 8786, and partial analyses of the plagioclase from the other rocks were made by Dr. W. H. Hillebrand. They are as follows:

	8786	8589	10440a	10440b
SiO_2	51.89	52.18	47.59	46.92
Al_2O_3	29.68	29.20	30.97	31.51
Fe_2O_3	.32	1.11	1.55*	1.29*
FeO	.37			
CaO	12.62	11.18		
MgO	.38			
K_2O	.50			
Na_2O	3.87			
H_2O (100°)	.07			
H_2O (above 100°)	.39			
Total	100.09			
Sp. Gr.	2.700	2.711	2.712	2.674

The figures under 8786 and 8589 correspond very closely with those of a basic labradorite. Those under 10440a and 10440b are abnormal, in that they indicate that the more basic portion of the feldspar in this rock has a lower specific gravity than the more acid one. The alumina in the four cases, however, corresponds quite well with the proportion of this oxide in basic labradorites. In Ab_1An_3, which Tschermak makes the dividing line between labradorite and bytownite, the percentage of alumina present is 32.8 per cent. Since the rock specimens from which these feldspars were separated represent the only phases of the gabbro that have retained the normal gabbro characteristics, it is probable that the feldspars themselves represent the variations within whose limits all of the feldspar in the great mass of the rock may be found. A comparison of this plagioclase with that of the very coarse diabase from the boss-like dike forming Pigeon

* All iron determined as Fe_2O_3.

Point, show it to be a little more acid than the latter, though not enough so as to cause it to be placed in a position in the plagioclase scale far removed from that of the feldspar of the diabase[1]. The corresponding figures for the two plagioclases are:

	SiO_2	Al_2O_3	Fe_2O_3 FeO	CaO	Na_2O
Gabbro	51.89	29.68	.69	12.62	3.87
Diabase	53.75	30.39	1.26	10.84	3.76

The augite is generally older than the plagioclase, although the latter mineral seems sometimes to mould the contours of the former one. The pyroxene occurs either in the interstices between the labradorite grains, or as narrow rims around the olivine, forming a mantle that surrounds these and separates them from the feldspar (see Fig. 1).[2] The mineral is very light colored, sometimes being almost colorless, but it is usually tinged

FIG. 1. Section of the olivine-gabbro, exhibiting the tendency of the pyroxene to include olivine grains. Section 1103. × 20.

with pink. It is moreover possessed of a diallagic parting, accentuated by dark decomposition products, the most abundant of which are tiny, irregular black and brown dots. These are scattered everywhere throughout the pyroxene, but are accumulated most thickly in the neighborhood of the cleavage lines. In some of the pyroxene pieces are the peculiar platy inclusions

[1] Bull. U. S. Geol. Survey, No. 109.

[2] Cf. M. E. WADSWORTH, Bull. No. 2, Geol. and Nat. Hist. Survey of Minn., Pl. III. Fig. 1. In this figure the author pictures a pyroxene and olivine bearing the same relation to each other as the diallage and olivine shown in Fig. 1 of this paper.

characteristic of gabbro diallage. These are often arranged in straight lines crossing the parting planes. They are frequently so crowded that the line of inclusions appears as a dark bar crossing the diallage at various inclinations to the cleavage, as in the most notable case (No. 8786), where the direction of the bar cuts the prismatic cleavage at 21° and on the same side of it as the extinction, which is 37° (see Fig. 2). Under polarized light the diallage appears as though polysynthetically twinned. The lamellæ holding the inclusions polarize with a slightly different

FIG. 2. Inclusions in Augite. Section 8786. × ca. 18.

color from that of the inclusion-free lamellæ. Moreover, the material in the immediate vicinity of the several inclusions seems to be more changed from its original condition than portions of the same lamellæ at a greater distance from them. This would indicate that the inclusions have absorbed some of the material of the pyroxene in their growth, and consequently that they are not original inclusions, as are those found by Williams[1] in the Cortlandt peridotites and norites, but are secondary like those discovered by Judd[2] in the peridotites and gabbros of the Western Islands of Scotland.

Under high powers a second cleavage can be detected as a series of fine lines perpendicular to the prismatic cleavage, in sections parallel to the vertical axis. Along these cleavage lines are disposed the inclusions with their long axes so arranged in the direction of the lines as to suggest that the latter were planes of easy solution—that the decomposition of the diallage first took place along them, and then attacked the pyroxene on both sides.

[1] Am. Jour. Sci., 3rd ser., vol. 31, 1886, p. 33; and vol. 33, 1887, p. 141.

[2] Quart. Jour. Geol. Soc., London, vol. 41, 1885, p. 354.

The only other alteration noticed in the diallage is along its edges, where brown and green hornblendes are developed, and in one case where the pyroxene is replaced in part by rosettes of chlorite that polarize in bright blue tints. The very deep pink color of some of the diallage plates may be due to incipient alteration, as along with the change in color there is produced a finely fibrous structure. The writer has searched earnestly for indications of enstatite[1] in the rock under consideration, but has failed to discover any, though strongly pleochroic hypersthene is present in large quantity in certain of its phases to be mentioned later. In one or two specimens of the normal gabbro there is also a little hypersthene, but it is not finely fibrous, and it occurs as very compact plates side by side with equally compact and very fresh plates of diallage.

Much of the pyroxene, as has been said, is in the interstices between the plagioclase and therefore is probably younger than this constituent. It is, however, not in the ophitic areas characteristic of diabasic pyroxene, but is usually in narrow stringers between the feldspar grains, and between these and the olivine. In some sections every grain of olivine is thus separated from plagioclase (Fig. 1), while in other sections, where this is not the case, the diallage is in too small quantity to serve this purpose. Narrow rims of this mineral also exist around magnetite and biotite, and they occur between these two minerals and olivine and a fibrous growth that surrounds them, especially the olivine, in a manner resembling a reaction rim.

Attempts to isolate the diallage for analysis were not successful, as it was found impracticable to free its powder from hypersthene and the brown earthy decomposition products of olivine.

The last mentioned mineral is usually quite fresh, and in large quantity, though in a few specimens it is represented by only an occasional grain in the thin section. Since it was one of the first separations from the magma yielding the rock, it is always present in more or less well defined idiomorphic grains. These are

[1] Cf. M. E. WADSWORTH: Nos. 787 and 692, pp. 90 and 91. Bull. No. 2 Minn. Geol. Survey.

transparent and almost colorless. In thick pieces a yellowish green tinge may be noticed, but in thin slices no recognizable tint may be detected. The inclusions are opaque dendritic particles, spongy magnetite, and secondary products, among which may be mentioned yellowish serpentine, chlorite, and opaque and yellowish-brown earthy substances. These may occasionally entirely replace the original mineral, but more frequently they occur only in the cleavage and other cracks in the fresh olivine, or along its edges.

In most cases the olivine is so fresh that it was thought worth while to have an analysis of it. This has been made by Mr. Hillebrand, who had furnished him a powder consisting of beautifully fresh olivine intermingled with a little diallage, the mixture having been separated from rock No. 8589 by means of methylene iodide. The olivine was isolated by digestion with hydrochloric acid, and the solution obtained was analyzed with this result:

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	CoO	NiO	CaO	MgO	H_2O	Total.
35.58	1.22	.92	tr.	33.91	.35	.20	?	.90	26.86	.31	100.25

The olivine is thus a hyalosiderite with Mg : Fe about 1½ : 1. The small quantities of manganese and cobalt present in it are of interest from the point of view of Sandberger,[1] as affording another indication that olivine is frequently that constituent of a rock which is the source of the material for ore segregations. In the present instance they are of little significance, however, since so far as known the only ores occurring within the large areas covered by the basal gabbro are magnetite and ilmenite. At Copper Lake, in Secs. 9 and 10, T. 64 N., R. 4 W., weathered masses of the gabbro are stained with a green coating of malachite, and the same[2] staining has been noticed at the contact of the Pigeon Point gabbro with a red granophyric rock, where it has resulted from the alteration of chalcopyrite, but in neither case is the copper compound in sufficient quantity to constitute an ore.

[1] Cf. J. F. Kemp: A Brief Review of the Literature of Ore Deposits. School of Mines Quarterly, XI., No. 4, p. 366.

[2] Bull. U. S. Geol. Survey, No. 109.

The relation existing between the olivine and the diallage is the most interesting of the phenomena presented by the rock. It has already been stated that but very few olivine-grains are in direct contact with feldspar. Around nearly all are narrow rims of pyroxene. At first glance these appear to be a sort of reaction rim between the two minerals, but a more careful study of the sections disposes of this assumption, for the surrounding rim frequently broadens out and merges into a well defined diallage plate (Fig. 3). In consequence of the occurrence of the olivine and augite in the manner described sections of the rock exhibit a

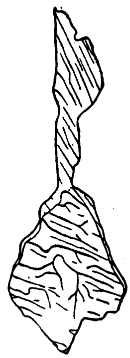

FIG. 3. Olivine partly surrounded by narrow rim of pyroxene, which is continuous with large plate of same mineral. 8803. × ca. 18.

kind of concentric structure, with the rounded olivine grains surrounded by a zone of diallage, and imbedded in a mass of plagioclase. Perhaps the most perfect exhibition of this association of the three minerals is shown in the section of rock No. 1103 from the Cloquet River, where the augite is in such large quantity as to completely envelop the olivine (see Fig. 1).

When the pyroxene is in smaller quantity the rim is much narrower, and in many cases is in its turn separated from the plagioclase by a fibrous growth between the last named mineral and itself. This fibrous growth imitates in great perfection many of the reaction rims described by various investigators[1] as exist-

[1] TORNEBOHM: Neues Jahrb. f. Min., etc. 1877, pp. 267 and 384. A. A. JULIEN: Geology of Wisconsin, vol. 3, p.235, Pl. 22. F. BECKE: Min. u. Petrog. Mitth. 1882,

ing between olivine and plagioclase in many basic rocks. It usually consists of very fine fibres extending perpendicularly from the bounding surfaces of the diallage rim, or when this is lacking, from the peripheries of the olivine grains. In a few instances the fibres form radial groups, centering at points on the exterior of the surrounded mineral. The growth is especially noticeable in the vicinity of the olivine, but it is occasionally also found bordering magnetite grains (Fig. 4) and flakes of biotite. The fact that the fibres are not confined to the borders

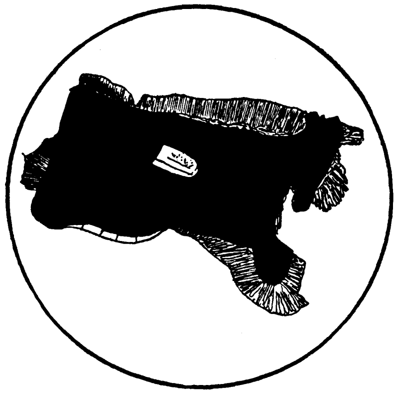

FIG. 4. Fibrous intergrowth around magnetite (?) Between the latter mineral and the fibrous rim can be seen a narrow zone of diallage. Section 10439. × 20.

of olivine, but are found as well around magnetite, biotite,[2] and outside of the diallage rims around olivine grains, is presumptive evidence that the growth is not of reactionary origin.

Between crossed nicols portions of the fibrous zone polarize brilliantly, while other portions have the pale blue tint of thin feldspar. Under very high powers the individual fibres are discovered to be discontinuous. They branch, fork and bend in a fantastic manner, and sometimes stop abruptly, while new fibres begin their courses some distance beyond and continue to the edge

iv., pp. 330, 350, 450. G. H. WILLIAMS: Bull. U. S. Geol. Survey, No. 28, p. 52. M. SCHUSTER: Neues Jahrb. f. Min. etc., B. B. v. p. 451. TEALL: Mineralogical Magazine, Oct. 1888, p. 116. LACROIX: Bull. Soc. France d. Min., 1889, xii., p. 83.

[2] The biotite is probably secondary so that the occurrence of the fibrous rim around it is of little importance as an aid in determining its nature.

of the rim. It is impossible to determine the character of the fibres in the finest rims, but in those in which the structure is coarser, it is learned that two components are present. One is possessed of a high index of refraction, and strong double refraction, and this appears to be continuous with the diallage of the narrow zones interposed between the fibrous growth and the surrounded olivine. The other component penetrates between the pyroxene fibres, and has club-shaped ends. Occasionally the twinning bars of plagioclase may be detected in it, and hence it is assumed to be a triclinic feldspar. The fibrous rim is thus an intergrowth of plagioclase and augite, both of which minerals are normal constituents of the gabbro. In the fibrous rims they have evidently crystallized contemporaneously, whereas in the main body of the rock the main portion of the diallage preceded the plagioclase in its separation from the magma. There is no necessity for regarding the intergrowths as in any way connected with reactionary processes, while there is abundant reason for believing them to be due solely to the tendency of simultaneously crystallizing minerals to mutually interpenetrate each other. This tendency is well recognized as existing to a marked degree between quartz and orthoclase, whereby granophyre is formed, and to a less extent between various other minerals. Micropegmatitic intergrowths between hornblende and feldspar, for instance, have been described by Lévy,[1] Camerlander[2] and Lacroix,[3] between hornblende and quartz by Kalkowsky,[4] between garnet and feldspar by Becke,[5] and between garnet and quartz by Lacroix (l. c., p. 317,) between diopside and quartz by Lévy,[6] and between various monoclinic pyroxenes and plagioclase by Becke (l. c.), Camerlander (l. c.), Lacroix (l. c., pp. 316 and 318), and Lévy.[7] In the Minnesota rock the diallage in many

[1] Bull. Soc. Min. d. Fr., 1878, p. 41.

[2] Ref. Neues Jahrb. f. Min., etc., 1888, II., p. 52.

[3] Bull. Soc. Franc. d. Min., 1889, XII., p. 319.

[4] Gneissformation, des Enlengebirges, p. 41.

[5] Min. u. Petrog. Mitth. 1878, p. 406.

[6] Bull. des Serv. d. l. Carte geol. d. l. France, No. 9, 1890, p. 7.

[7] Ib. p. 7.

instances sends out tongue-like processes that penetrate far into the plagioclase in which the pyroxene is imbedded (see Fig. 5), so that there can be no doubt that the conditions were favorable to the formation of intergrowths between these two minerals during the period when they were separating from the rock magma. The only essential differences between the fibrous

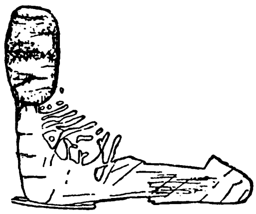

FIG. 5. Diallage plate and olivine grain in plagioclase. The augite in the bend extends out into the feldspar, giving rise to an intergrowth, very like that of the fibrous rim. 8803. × ca. 20.

intergrowths and that illustrated in this figure are, first, the finer structure of the former, and second, its occurrence around the older components of the rock. Neither of these differences is important, however. Only the second needs a moment's consideration.

The position of the fibrous growth around the olivine and other minerals is due not necessarily to the fondness of the intergrowth for this place, but simply to the fact that the diallage, during the earlier stages of its growth, fastened itself to the solid particles in its vicinity and coated them with an envelope of its material. Continuing its growth it formed the encircling rims of this material that are so characteristic of many specimens of the gabbro, and, when the feldspar began to separate it formed with this the granophyric intergrowth. Since the position of the diallage had already become fixed, the intergrowth naturally was compelled to occupy a place just without this and around the minerals which the diallage had already partially or entirely encircled.[1] Though a fibrous intergrowth of pyroxene and plagioclase with the aspect of a reaction rim surrounding the older minerals of a rock is a rare phenomenon, it is not a unique one, for

[1] For fuller description of the intergrowth, see author's paper in Am. Jour. Sci. XLIII., 1892, p. 515.

Camerlander,[1] in 1887, described a similar intergrowth of these two minerals around the garnets of a contact rock from Prachatitz, in the Bohemian Forest, and mentioned that it strongly resembled the kelyphite rims around garnets in serpentine.[2]

Biotite is present in many sections of the gabbro, though not in all. It not only occurs in the neighborhood of magnetite, where this mineral is in contact with plagioclase, but it is sometimes found imbedded in the feldspar and augite, and at other times it forms a mosaic with decomposed diallage. In basal sections it is reddish brown, and in longitudinal sections is light yellow normal to the cleavage, and dark brownish-green, almost opaque, parallel to this structural feature. In all cases it is probably secondary, for, even when it apparently occurs alone, a very close inspection of its sections will often reveal remnants of magnetite grains imbedded in it. This form of the mineral is evidently a reaction product between the magnetite and the plagioclase by which it is surrounded. The remainder of the mica is probably derived mainly from diallage, since when this mineral is perfectly fresh biotite is absent from the rock, and when the pyroxene has undergone any kind of decomposition, little flakes of biotite are intimately intermingled with its undoubted alteration products. In the broad pieces of diallage in which the dark platy inclusions are so common, little flakes and tiny needles of biotite are frequently discovered lining the cleavage cracks, so that such pieces not uncommonly are crossed by two sets of inclusions cutting each other at some acute angle, one set comprising the gabbroitic kinds already described, and the other set the biotite plates along the cleavage cracks.

Magnetite is widespread throughout the rock, but it is not abundant in most sections. It is in small grains, and in tolerably large areas that are broadly rod-shaped or very irregular in outline. In most cases it occurs between neighboring plagioclase

[1] Jahrb. d. K. K. geol. Reichsanst, 37, 1887, p. 117.

[2] The writer is informed by Dr. J. J. Sederholm that intergrowths similar to those occurring in this Minnesota rock are common in Norwegian gabbros and in one from Ylivilska, in Finland. In his university lectures Professor Brögger calls them "coronites."

grains, but sometimes it is included within them. The larger part of the mineral is undoubtedly primary, while a smaller portion is probably secondary. By its alteration it gives rise to biotite, as mentioned above, through reactions set up between it and the contiguous plagioclase, so that often a grain of the magnetite is entirely surrounded by a true reaction rim composed entirely of biotite. Leucoxene decomposition products were not once observed.

Nowhere in the normal gabbro does the magnetite occur in sufficient amount to constitute an ore, but in certain phases of the rock that have lost entirely the gabbro characteristics, it is known to exist in great quantities. Prof. Winchell[1] describes these ores in detail and gives analyses of them; but most of the titaniferous magnetites of this author's gabbro-titanic-iron group do not occur in the normal rock of his basal mass. They are found either in its peculiar phases to be described later, or in the Animikie and Keweenawan coarse-grained diabases, whose magnetite is always highly titaniferous, and in which there is always an abundance of leucoxene. Only a few qualitative tests have been made on the magnetite separated from the gabbro, but they all agree in showing no trace of titanium. If, upon further investigation, it is found that an absence of titanium from the magnetite of the basal gabbro is characteristic for the rock, an important difference will have been discovered as existing between it and the rocks of the interleaved flows of nearly similar composition in the underlying and overlying series.

The only other original component seen in any sections is apatite. This is in the usual form, as colorless, acicular crystals imbedded in feldspar, and in the various alteration products of the diallage and olivine. It is present only in very small quantity.

Quartz is rare as a secondary substance, mingled with other secondary products in the most altered phases of the rock. In one section (No. 8796) it is filled with tiny, opaque, acicular inclusions.

In order to learn something of the limits through which the rock varies in its chemical composition two specimens were

[1] Bull. No. 6. Minn. Geol. Survey, p. 117 and 125.

analyzed by Dr. H. N. Stokes of the laboratory of the U. S. Geological Survey. No. 8589 contains a large proportion of diallage and olivine, while No. 8786 is more nearly of the average composition of the entire mass.

	8589	8786
SiO_2	45.66	46.45
TiO_2	.92	1.19
P_2O_5	.05	.02
Al_2O_3	16.44	21.30
Cr_2O_3	tr.	
FeO	13.90	9.57
Fe_2O_3	.66	.81
NiO	.16	.04
MnO	tr.	tr.
CaO	7.23	9.83
MgO	11.57	7.90
K_2O	.41	.34
Na_2O	2.13	2.14
H_2O at 105°	.07	.14
H_2O above 105°	.83	1.02
Total,	100.03	100.75

The larger percentages of Al_2O_3 and of CaO in 8786 as compared with 8589, and the smaller percentages of FeO and MgO, substantiate the results of the microscopical study. An increase in the proportions of Al_2O_3 and CaO indicates an increase in labradorite, and a decrease in FeO and MgO, a decrease in the iron-bearing minerals olivine and diallage. The variations are somewhat larger than was to be expected in a rock so uniform in structure and so monotonous in composition as that of this great mass, but they are easily accounted for by the local accumulation of certain of its heavier constituents. So far as known there are no "schlieren" in the normal rock nor any other evidences of a differentiation ("spaltung") of its magma before cooling, so that the variations in mineralogical and chemical composition must be looked upon as due purely to accidental causes. Moreover, the differences are not great enough to effect any material impression upon the rock as a whole. Its characteristics are practically identical throughout an area of several thousands of square miles, and are

quite different from those of the comparatively thin flows between the sedimentary layers of the Keweenawan.

Prof. Winchell, in his bulletin on The Iron Ores of Minnesota, asserts[1] that the "gabbro is found associated with red syenite, quartz-porphyry and various sedimentary rocks in northeastern Minnesota, and, indeed, it passes through unimportant petrographic changes into the well known 'traps' of the cupriferous formation, from which it has not yet been possible to separate it by any important lithologic or stratigraphic distinctions." But since Prof. Winchell has included within his gabbro the rocks of Bellissima Lake, Carlton's Peak and the feldspar masses enclosed in the dark trap of Beaver Bay, it is plain that he does not confine his remark to the rock to which the writer is now limiting his attention, viz., the great coarse gabbro which Irving described as the great basal flow of the Keweenawan. This rock, as has been shown, by a study of specimens taken from very many different localities (see list of specimens studied, p. 714) within the area underlain by it, is so very uniform in its characteristic features that no difficulty is experienced in distinguishing its thin sections from those of any other rock in Minnesota north of Lake Superior.

Summary.—The microscopical study of the gabbro of Irving's "basal flow" at the bottom of the Keweenawan in Minnesota reveals a rock which is uniform in texture and composition throughout its entire extent. It is composed of magnetite, olivine, diallage and labradorite as essential constituents, with a little biotite and occasionally a very small quantity of quartz as secondary components. Its structure, or better texture, is typically granitic in that all of its comprising minerals are hypidiomorphically developed, with the plagioclase younger than the diallage. In this respect the rock is essentially different from the so-called gabbros of the thick flows interbedded with the clastic beds of the Animikie series and the Keweenawan group in the same region, for in the latter, notwithstanding the

[1] L. c., p. 124.

coarseness of their grain, the plagioclase is always older than the diallage, and it always possesses in greater or less perfection the lath-shaped sections characteristic of diabasic feldspar. This being the case, it seems possible that the great gabbro of north-eastern Minnesota is not a "flow" or a "series of flows," but is the solidified reservoir [1] in which later flows originated or is a batholitic mass, as Winchell[2] has latterly come to call it.

Further field work on the geological relationships of the mass will probably show either that it is a batholite within the Keweenawan series, well down toward its base, or that, like the anorthosites of Lawson it is an eroded "massive" upon the top of which the later Keweenawan beds have been deposited.

List of Specimens of Normal Gabbros Studied and their Locations.

1103 (338) 400 N. 200 W. S.E. corner Sec. 34, T. 53 N., R. 13 W., Minn.
6007 (1415) S. side Cross Lake, S. side Sec. 29–64–1 W.
(1416)
(1424)
6011 (1126) S.E¼ Sec. 21–64–3 W.
6013 (1127) N.W. side Copper Lake, Sec. 9–64–4 W.
6127 (1171) N.E¼ S.W¼ Sec. 36–65–3 W.
6128 (1172) S.E¼ S.W¼ Sec. 36–65–3 W.
6130 (3203) S.E¼ S.E¼ Sec. 36–65–3 W.
7025 (2091) S. shore Akeley Lake, Sec. 29–65–4 W.
8589 (4025) S. shore of small lake in S.E¼ S.E¼ Sec. 19–63–9 W.
8786 (3520) Near S.¼post of Sec. 35–61–12 W.
8788 (3528) N. shore Birch Lake, 200 paces E. of S.¼post Sec. 24–61–12 W.
8789 (3529) W. side Birch Lake, opposite N.E. arm of lake, Sec. 24–61–12 W.
8792 (3532) N.W¼ S.W¼ Sec. 9–62–10 W.
8793 (4259) N.W¼ S.E¼ Sec. 23–62–10 W.
8794 (3522) On Mishiwishiwi river, near centre Sec. 34–62–9 W.

[1] Cf. *ante*, p. 696.

[2] Bull. No. 8, Geol. and Nat. Hist., Sur. of Minn. Preparatory note, P. xxiv. *et seq.*

8795 (3534) On Mishiwishiwi river, near centre of N½ T. 61–7 W.
8796 (3848) On Mishiwishiwi river, about 2 miles E. of 8795.
8800 (3535) On Mishiwishiwi river, near S. side T. 62–8 W.
8803 (3537) S.E¼ N.E¼ Sec. 7–63–8 W., 250 paces S. of S.E. point of Snowbank Lake.
8869 (4061) S.E¼ Sec. 14–64–7 W.
8896 (3856) N.W¼ Sec. 6–64–5 W.
10000 (3691)
10438 (5068) Half way down W. side Greenwood Lake, Sec. 29–64–2 E.
10439 (5069) Outlet Greenwood Lake, Sec. 33–64–2 E.
10440 (5013) Ca. S.E¼ Sec. 8–59–10 W.
10441 (5014)
10442 (5015)
10443 (5016)
10444 (5070)
10445 (5071)
} In order from S. to N. along a stream running from a small lake northward into Birch Lake. First specimen from about N. side of T. 59 R. 10 W.
10537 (5160) S.E¼ S.W¼ Sec. 33–65–5 W.
10538 (4985) S.E¼ S.E¼ Sec. 32–65–5 W.
10539 (4986) S.W¼ S.E¼ Sec. 32–65–5 W. East end of portage between lake Kabamitchikamak and small lake in Sec. 32–65–5 W.
10569 (5181) 1200 paces south N.W. corner Sec. 29–65–4 W.
10570 (4995) 1500 paces S. of N.W. corner Sec. 29–65–4 W.
10638 (5242) North of centre of Sec. 18–64–3 E.

SHOWING APPARENT REACTION RIMS.

6130 (3203), 7025 (2091), 8792 (3532), 8793 (4259), 8795 (3534), 8800 (3535), 8803 (3537), 10000 (3691), 10439 (5069), 10442 (5015), 10444 (5070).

NOTE.—The first number given in each case is the number of the specimen in the collection of the Lake Superior Division of the U. S. Geol. Survey. The numbers in parentheses are those of the corresponding thin sections.

W. S. BAYLEY.

WATERVILLE, ME., July 1, 1893.

Correction.— In the reference (on page 591 of this Journal) to Dr. Wadsworth's work on the Intrusive Basic Rocks of the Marquette region, the date of the publication of the "Notes on the Geology of the Iron and Copper Districts of Lake Superior," is given as 1881. It should be 1880.

It is also stated on the same page that Wadsworth declared these rocks to consist largely of diabase and coarse basalt, both massive and slightly schistose. It was, of